July 22, 1952 E. E. J. GAISSET 2,603,978

EXTENSIBLE PULLEY

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Fig. 1.

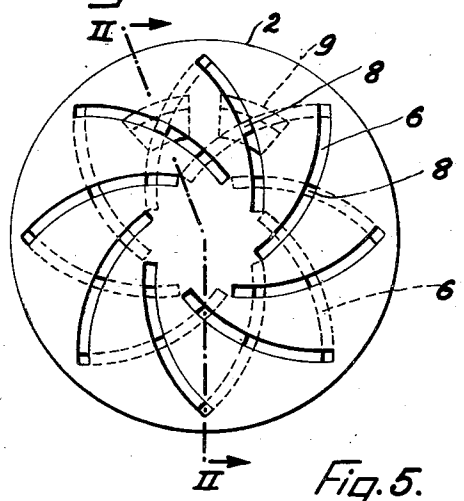


Fig. 2.

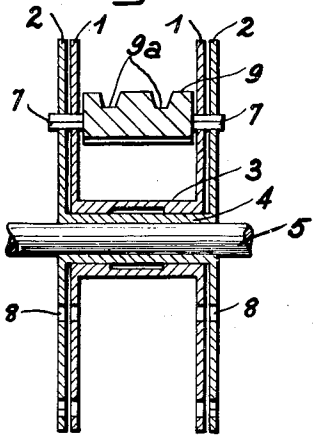
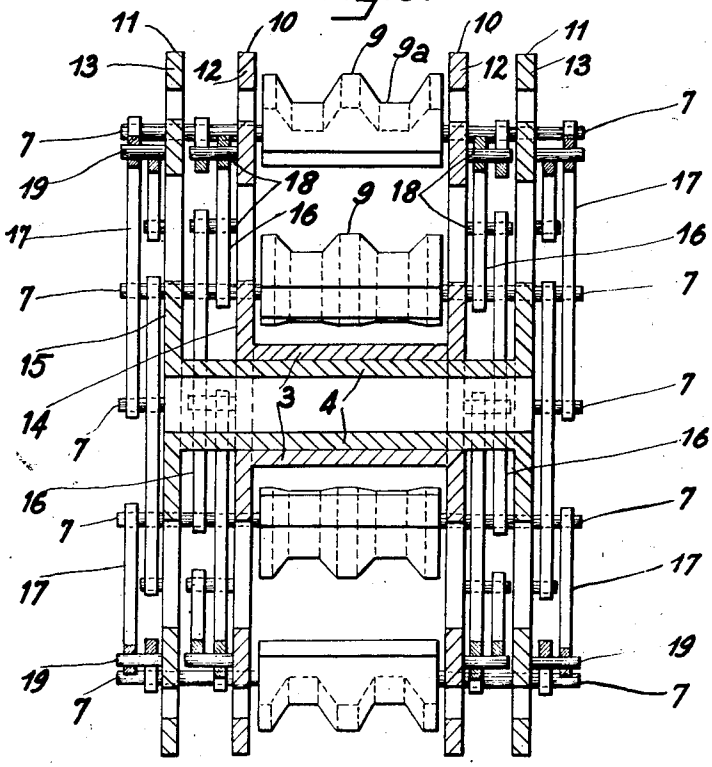


Fig. 5.



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Fig. 3.

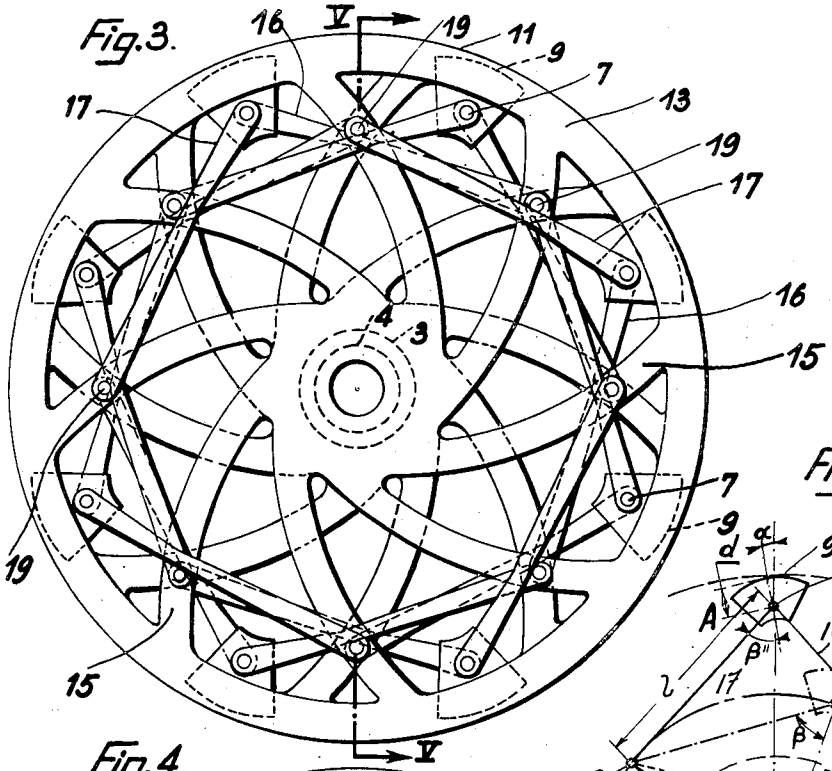


Fig. 6.

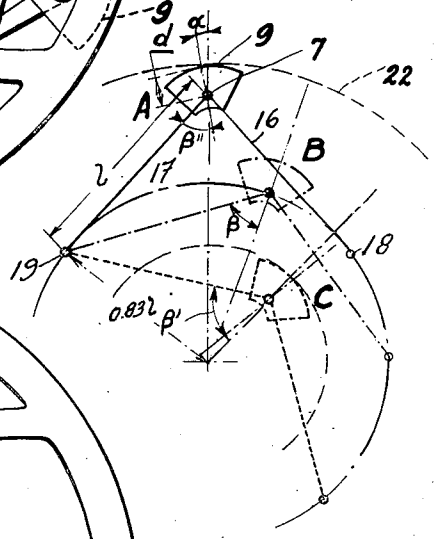
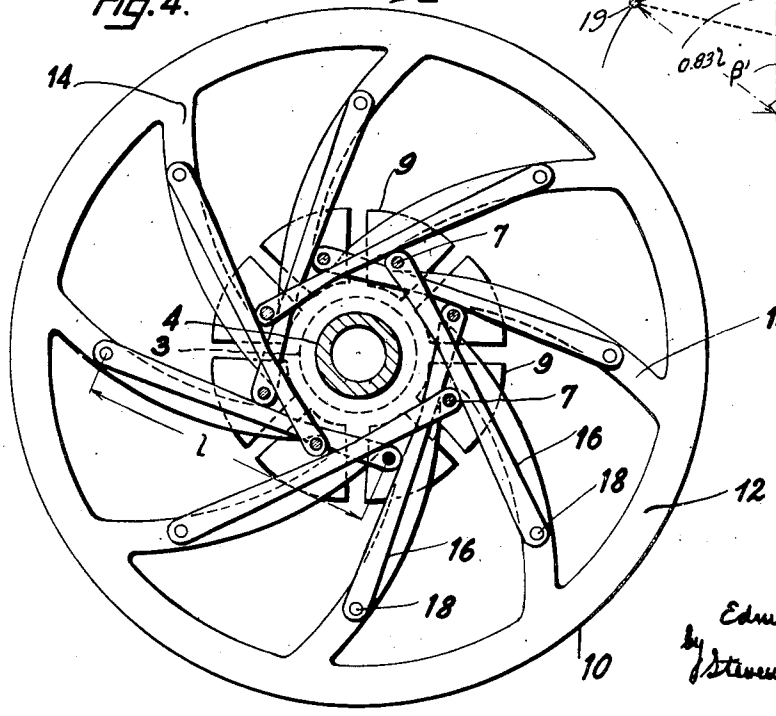


Fig. 4.



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EXTENSIBLE PULLEY

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Fig. 7.

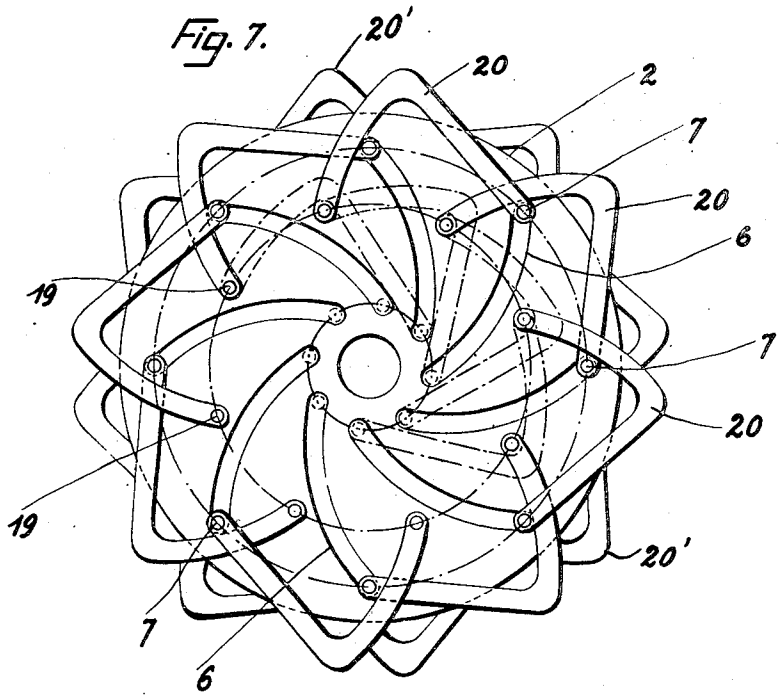
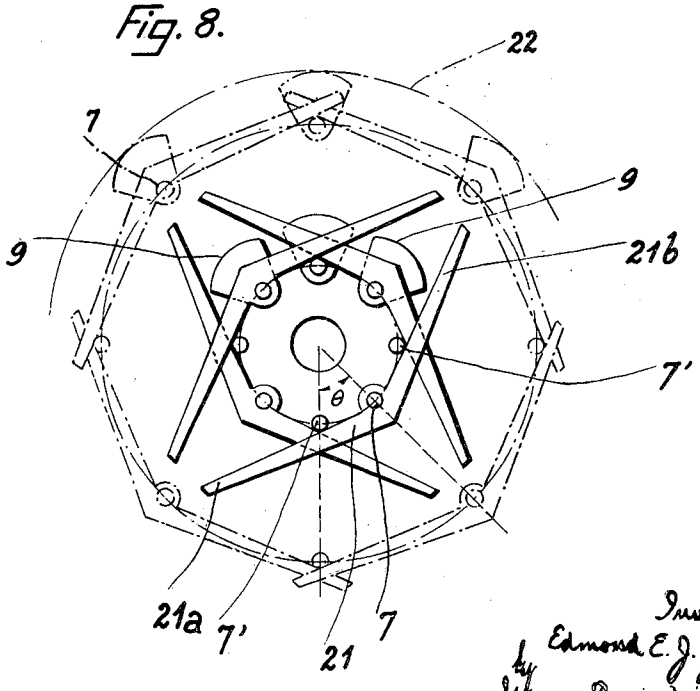


Fig. 8.



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EXTENSIBLE PULLEY

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Fig. 9.

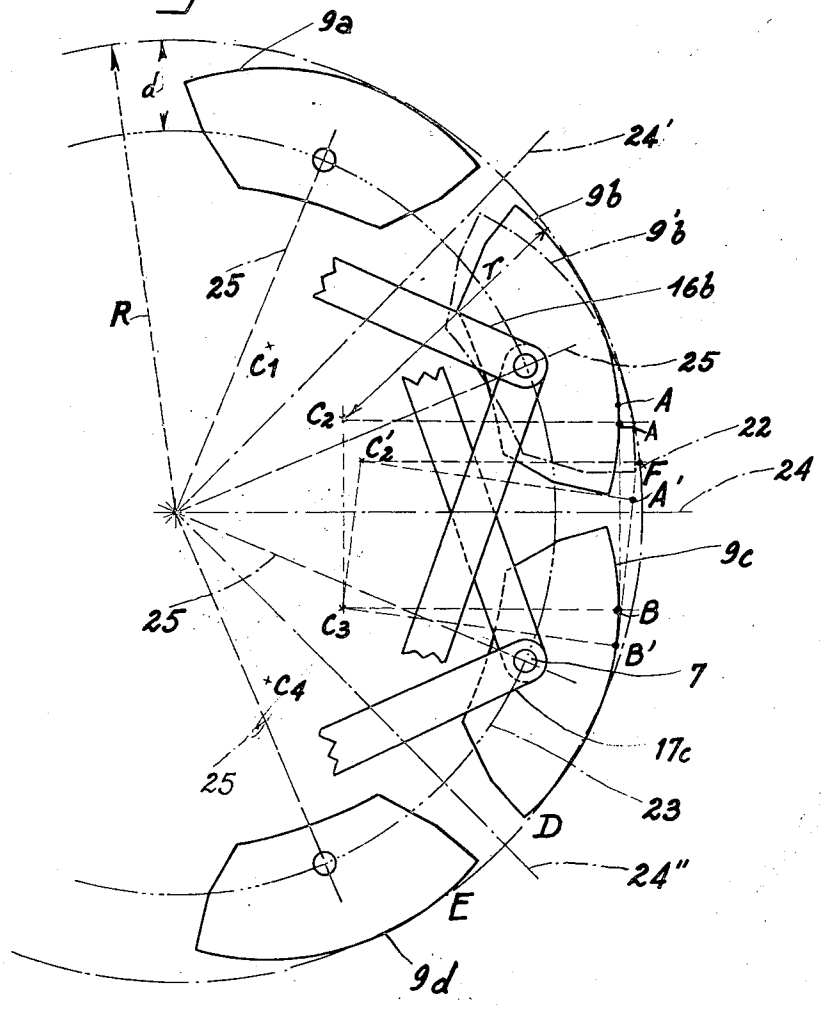
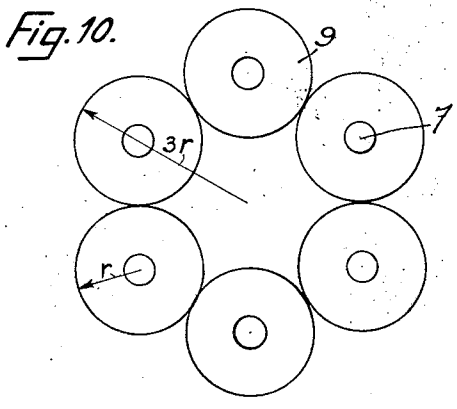


Fig. 10.



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UNITED STATES PATENT OFFICE

2,603,978

EXTENSIBLE PULLEY

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Application February 7, 1949, Serial No. 74,874
In France February 9, 1948

6 Claims. (Cl. 74—230.22)

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Extensible pulleys having discontinuous rims formed by rim segments radially displaceable by means, for instance, of paired slots provided in two adjoining disks liable to rotate relatively to each other, are already known.

According to the relative position of the two disks, the opening at the intersection of two paired slots into which is engaged the support of a rim element, is located nearer to or further from the centre of the pulley, this enabling to vary the diameter of this pulley.

The object of my invention is to improve extensible pulleys formed by radially movable rim segments.

One of the objects of the invention is the suppression of noise and wear occurring in known pulleys.

Another object of the invention is a better guiding of the radial motion of the rim elements.

Another object of the invention is the suppression of the causes of wear and tear of straps due to a sudden change in curvature owing to the discontinuity of the periphery of these pulleys.

The invention will be made fully apparent in the following description, reference being had to the accompanying drawings in which:

Fig. 1 is a side elevation diagram of a known pulley.

Fig. 2 is a cross-section along line II—II of Fig. 1.

Figs. 3 and 4 are two similar side elevations of a pulley according to the invention, at its maximum and minimum diameters respectively, the paired flanges being in position in Fig. 3, and the inner flange only being apparent in Fig. 4.

Fig. 5 is a cross-section along line V—V of Fig. 3.

Fig. 6 is a diagram showing the extreme positions of a rim element of the pulley, and an intermediate position.

Fig. 7 is a side elevation of another embodiment of the invention.

Fig. 8 is a digaram showing a device designed for preventing the rim elements from turning about their pins.

Fig. 9 is a diagram of a particular arrangement of rim elements.

Fig. 10 shows geometrically the position of rim elements of a six element pulley, at minimum diameter.

The pulley shown in Figs. 1 and 2 is described in French Patents Nos. 687,559 of November 19, 1929 and No. 859,008 of August 11, 1939, filed in the applicant's name.

This pulley has two sides each of which is

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formed by two disks—an inner one 1, and an outer one 2—which are integral with two coaxial sleeves 3 and 4 respectively, the latter being secured to shaft 5.

In disks 1 and 2 are provided curvilinear slots 6 regularly distributed over each one of them, but the slots in one of the disks are directed in the opposite way relatively to the slots in the adjoining one. The tips of pins 7 integral with each rim element 9, cross curvilinear quadrilateral openings 8 at the intersections of slots 6 provided in the paired disks. If slots 6 have the shape of logarithmic spirals whose tangent makes a constant angle of 45° with the radius vector, two spirals provided in two adjoining disks always cut at right angles, so that, if pins 7 have a square cross-section, they are centred and guided between the four portions of edges of slots 6 forming together an opening 8 whose outline is roughly that of said cross-section.

Owing to the motion of pins 7 along slots 6, the rotation of disks 1 relatively to their paired disks 2 causes every rim element 9 to move radially towards the centre or the periphery, by the same amount. Moreover, these elements are kept in a constant direction relatively to the disks, because a rotation of pins 7 in openings 8 cannot occur owing to the shape of the pins. Rim elements 9 thus form together an extensible pulley rim either for a flat strap or for trapezoidal ones if grooves 9a are provided. The diameter of this pulley may be altered by causing anyhow disks 1 and 2 to rotate relatively to one another. This rotation may merely be the result of centripetal forces exerted by the strap on the elements, on the one hand, and of centrifugal forces exerted on rim elements 9, on the other hand, this causing the pulley to automatically adjust according to the assigned resistant or driving couple.

This pulley, although very attractive in principle, nevertheless bears numerous disadvantages.

If slots 6 are accurately in the shape of logarithmic spirals, their curvature is variable, so that the sides of pin 7 cannot properly rest on the edges of openings 8 in every position of the latter.

If, on the contrary, these slots are given a circular shape even if it is roughly that of a logarithmic spiral, the intersection angle of two slots is no longer constant; hence, pins 7 may get jamed in openings 8. Anyway, in order to allow sliding, a certain clearance is required, this causing noise and wear.

The object of the present invention is to cope with these disadvantages.

In the embodiment shown in Figs. 3, 4 and 5, the slotted disks 1 and 2 are replaced by circular flanges 10 and 11, each formed of an annular rim 12, 13 connected to the respective coaxial sleeves 3, 4 by means of spokes 14, 15 of an appropriate shape designed to allow free passage in every position, to pins 7 of rim elements 9. Each of these pins 7 is freely held, at its tips, at one end of a tie-rod 16 and at one end of a corresponding tie-rod 17, the other ends of these tie-rods being hinged upon pivots 18, 19 respectively, carried by flanges 10, 11 respectively, tie-rods 16 being inversely directed relatively to tie-rods 17.

Owing to this arrangement, a rim element 9 supported by two tie-rods 16 and two tie-rods 17, may occupy any position between that corresponding to the maximum diameter of the pulley (Fig. 3), and that corresponding to the minimum diameter (Fig. 4) by a mere relative rotation of the two flanges 10 and 11.

Flanges 10 and 11 are only designed to carry pivots 18 and 19 and to prevent any lateral displacement of tie-rods 16, 17 and rim elements 9.

In this example, the pulley comprises eight rim elements. It may be shown by calculation that if pivots 18, 19 are distributed over a circumference of radius $0.83l$, with l being the operative length of the tie-rods, the maximum radius of the pulley is approximately l, whereas the minimum radius may be as low as $0.3l$ roughly (see Fig. 6).

Fig. 5 shows the arrangement and size of pivots 18, 19, designed to allow free movement of tie-rods 16, 17 between their extreme positions without hindering each other, even if they are rectilinear; and the more so, if they are bent.

The angle between two corresponding tie-rods 16, 17 leading to a same pin 7 will always be approximately 90° without ever increasing beyond that value by more than 22° at the most, during changes in the diameter of the pulley.

These proportions are obviously only given by way of example. They allow, for a given pulley, a change in diameter in the ratio of 1:3, i. e. for a device containing two such pulleys in cooperation, a change in the ratio of 1:9 which is very convenient for practical use.

However, if a ratio greater than 1:3 between the extreme diameters, is required, two sets of L-shaped tie-rods 20 and 20' (Fig. 7) may be used instead of the previous sets of tie-rods 16 and 17. These tie-rods 20, 20' are arranged so that pins 7 held at their ends be always situated inside the concavity of the following L-shaped tie-rod.

Slots 6 similar to those of Fig. 1 but a little wider are provided for the free displacement of pins 7. The positions of the tie-rods giving the maximum diameter are shown in full line, and the positions giving the minimum diameter are shown in broken line.

In practice, the tie-rods are given the smallest possible thickness, so as to decrease the lateral overall dimensions of the whole. As shown in Fig. 5, tie-rods 16 hinged upon pivots 18 carried by flanges 10, are located between flanges 10 and 11, whereas tie-rods 17 whose pivots 19 are carried by flanges 11, are outside the latter. Moreover tie-rods 16 as well as tie-rods 17, are alternately distributed in parallel planes perpendicular to the axis of shaft 5, so that the movements of these tie-rods cannot hinder each other.

In the shown example, tie-rods 16, as well as tie-rods 17, being alternately placed in two parallel planes, if it is assumed that the thickness of the tie-rods is equal to that of the flanges which all have the same thickness, the overall dimensions on either side of the pulley may be reduced to six times the thickness of a disk.

The position of pins 7 determines that of rim elements 9. However, for the pulley to fulfill its function, it is important that those rim elements 9 be prevented from rotating about these pins 7 during rotation of the pulley, under the exertion of tangential forces due to the strap.

A first means to achieve this result consists in securing each rim element 9 by means of a flat key 21 (Fig. 8) whose outline is such that its edges $21a$ and $21b$ be in contact with pins 7' of the next rim elements on either side of pin 7 carrying the considered rim element 9. The angular interval θ between pins 7 and 7' remaining constant, edges $21a$ and $21b$ of key 21 are in contact with pins 7' whatever be the diameter assigned to the pulley.

The set of keys 21—shown in full line in the case of the minimum diameter and in broken line in the case of the maximum diameter—prevents the rotation of the four rim elements 9 about their pins 7. As for the elements carried by pins 7', a similar set of keys is provided on the other side of the pulley. It is identical to the one shown in Fig. 8 but shifted relatively to it through an angle of 45°.

It should be noted that the radius of curvature of each rim element must be at the most equal to the minimum radius of the pulley in the state of maximum contraction, so that no impact takes place in the strap during passage from one element to the other.

Another way of preventing rotation of rim elements 9 about their pins 7, consists in securing these pins to the ends of one of the sets of tie-rods 16 or 17, and freely holding them at the ends of the tie-rods of the other set.

Under those conditions, each rim element 9 lies along a direction depending on the position of the tie-rod to which it is secured. During changes in dimensions of the pulley, the angle α made by the axis of each of these rim elements and the radius of the pulley passing through its pin, is altered by a certain angle when the tie-rod moves (Fig. 6). For these rim elements to always remain tangent to the strap wrapping them, it is enough for their radius of curvature to be at least equal to the distance d between pins 7 and the primitive circle 22 (Fig. 6) of the pulley, but it is necessary, in order to avoid exaggerated bendings of the strap that the radius of curvature thus determined be greater than the radius of the pulley of minimum diameter required by the normal use of said strap. As a matter of fact, particularly in the case of trapezoidal straps, it is known that there is, for each of them, a minimum diameter of the pulley around which it may be wound without excess of strain or wear.

The simplest solution consists in giving the elements a radius of curvature r equal to the minimum radius of the pulley compatible with the strap, in making the support pin of these elements coincide with their centre of curvature, and in giving these elements a peripheral development large enough for their rim to be tangent to the strap, at the points at which the strap comes into contact with the elements, during their rotation about the pins. This condition entails producing the periphery of the element at least

up to the tangential point of the rectilinear portion of the strap and the primitive circle of the element.

But this solution has the disadvantage to entail pulleys of exaggerated dimensions.

Indeed, assuming, in order to simplify, that the pulley comprises six rim elements and that the peripheral development of each of them is very nearly a complete circle, it may be easily seen in Fig. 10 that the smallest possible radius of the pulley is $3r$. If it is wanted to have a variation of 1 to 3 between the smallest and the largest diameters of the pulley, the diameter of the pulley at its maximum extension will be $18r$, i. e. this pulley will be very heavy and clumsy. Anyhow, it is easy to see that if the number of elements is greater, the minimum diameter, and hence the maximum diameter are greater.

It will be shown hereunder that it is possible to obtain extensible pulleys with elements whose radius of curvature is very nearly the minimum allowable radius, these pulleys being liable to be reduced down to a radius a little greater than the minimum radius. Indeed, for a rim element **9** of given curvature to be utilizable in an extensible pulley according to the invention without damage to the strap, it is necessary—

That the tangential plane common to two successive rim elements really touches the circular cylindrical portion represented by each of them and not the extension of that cylindrical portion outside the element,

That from the point of contact of the strap to the point at which that strap tangentially leaves the element in question, the arc of the element subtended by the strap must be equal to

$$\frac{2\pi}{n}$$

n being the number of elements in the pulley.

In other words, these two conditions mean that it is necessary that the bending of the strap entirely occurs on the cylindrical surface of the rim element, i. e., that the strap leaves the rim element **9** on either side tangentially to its cylindrical surface, and not around its outer edge.

If these conditions are not complied with, the strap wrapping two consecutive elements and offering, owing to its tension, an intermediate rectilinear portion, makes a certain angle with the tangent at the point of contact with one of the elements, this entailing a sudden increase in the curvature of the strap around the outer edge of the rim element, thus overstraining it.

On the contrary, these two conditions are complied with if the peripheral development of each of these elements is at least equal to the arc

$$\frac{2\pi}{n}$$

(for the radius of curvature of the element) increased by twice the arc (for a radius equal to the distance between the pin of the elements and the primitive circle) corresponding to the maximum angle α through which its direction may vary around its mean position.

Mean position means the position (B in Fig. 6) in which the symmetry plane of each element **9** passes through the axis of the pulley and forms with the tie-rod an angle β equal to the mean of the maximum angle β' and the minimum angle β'' made by that tie-rod with the radius passing through the pin carrying the rim element during its displacement between the extreme positions. If for instance, $\beta'=58°$, and $\beta''=50°$, the mean position corresponds to $\beta=54°$ which determines a value for the radius of the pulley. For this position the rim element will be wedged to the tie-rod so that its symmetry plane passes through the axis of the pulley.

It may be proved that by conveniently choosing the wedging of each element **9** relatively to one of the tie-rods **16** or **17**, the change in direction of the elements, in other words, the angle made by the symmetry plane of an element with the diametrical plane of the pulley passing through pin **7** supporting it, may be reduced to a minimum not exceeding in practice a few degrees.

The peripheral development of each of the elements thus defined by observation of the conditions of correct operation of the strap, may nevertheless be so great that it assigns a value yet too large for the minimum diameter of the pulley, i. e. diameter obtained when all elements are brought, in contact with each other, owing to centripetal motion.

This fact will be clearly apparent in the description given with reference to Fig. 9 showing a way of coping with this disadvantage.

In that figure, one half of an eight rim element pulley has been shown, i. e. four of these elements **9***a*, **9***b*, **9***c*, **9***d*. The centres of curvature of these elements are located in C_1, C_2, C_3, C_4 i. e. the radius of curvature r is far superior to distance d between the centre of pins **7** and the primitive circle **22** of the pulley. Pins **7** are regularly distributed over a circle **23** having a variable radius equal to $R-d$, R being the radius of the primitive circle **22** of the pulley for the considered position of the tie-rods and pivots.

It is noted in the figure, that elements **9***a* . . . **9***d* have been secured to their tie-rods so as to be symmetrical, two by two, about the diametrical planes **24** bisecting the diametrical planes **25** passing through pins **7**.

Indeed if elements **9***b* and **9***c* are considered, the first one is secured to tie-rod **16***b*, whereas the second one is secured to tie-rod **17***c*. The same occurs in the case of the other elements which are alternately secured to tie-rods of set **16** and of set **17**. As the two tie-rods **16***b* and **17***c* for instance, in the relative rotation of the two flanges **10** and **11** remain symmetrical about plane **24**, elements **9***b* and **9***c* will also remain thus in every position, if they have been appropriately wedged relatively to their respective tie-rods, so as to fulfill this condition, for any determined position. In practice, their wedging relatively to their respective tie-rod is ensured in such a way that, in the position defined as the mean position, the plane of symmetry of each of these elements **9** coincides with the diametrical plane of the pulley passing through the joint axis of the corresponding elements.

The figure is assumed to be drawn for a position of the elements distant from their mean position and nearly corresponding to the minimum radius of the pulley. Element **9***b* being symmetrical with element **9***c* about plane **24**, centre of curvature C_2 of element **9***b* is also symmetrical with centre of curvature C_3 of element **9***c*, i. e. straight line C_2C_3 is perpendicular to plane **24**. Consequently, the common tangent AB of these two elements is parallel and equal to C_2C_3.

If the alternation in securing the elements to tie-rods **16** and **17** is kept, centre of curvature C_1 of element **9***a* is also symmetrical about plane **24'** with centre C_2 of element **9***b*; similarly, centre C_4 is symmetrical with C_3, about plane **24''**.

As the strap wraps each element over an angle

$$\frac{2\pi}{n}=45°$$

in the case of an eight element pulley, the linking up tangent DE between elements 9*c* and 9*d* for instance, is parallel and equal to C_3C_4. Hence, whatever be the dimension of the pulley, these portions of tangent keep the same direction, and the shape of the strap on the pulley is always that of a polygon (octagon in the given example) $C_1C_2C_3C_4$ . . . whose sides of variable length have a constant relative direction, two adjacent sides of that polygon being linked up by a constant radius arc of a circle subtending an angle of 45°.

If during the change in dimension of the pulley, angle α (Fig. 6) between the symmetry plane of an element and the diametrical plane passing through its pin remains small, the sides of the polygon are little different from each other and no disturbance of operation is caused for the pulley. And this arrangement offers the great advantage of reducing the peripheral development of each element.

Assuming element 9*b* has the same direction as elements 9*a* and 9*c* which lie on either side of it, which practically means that all elements are secured to the set of tie-rods 17, for instance. Under these conditions, during a change in dimension of the pulley, every element turns about pins 7 in the same direction. Hence, element 9*b* occupies the position shown by dotted lines 9'*b* (Fig. 9) and its centre of curvature is then in C'_2. The common tangent A'B' to elements 9'*b* and 9*c* is then equal and parallel to $C_3C'_2$. But, it may be noticed in the drawing that point A' is virtual, i. e. it does not lie on element 9'*b* but on its extension. In order to enable the strap to tangentially reach element 9'*b*, i. e. avoid bending it on the edge of element 9'*b* along a radius incompatible with its proper operation, the peripheral development of each element should be increased at least by the length A'F. It is obvious that this increase in the peripheral development of the elements restricts the possibility of reducing the diameter of the pulley because of the premature engagement into contact of the elements.

On the contrary, with the proposed arrangement of symmetrical direction for two adjoining elements, about the diametrical plane 24 bisecting both diametrical planes 25 passing through pins 7, the peripheral development of a rim element may remain small even with a radius of curvature far greater than the distance between the pins and the primitive circle 22 of the pulley.

It is sufficient, in order to ensure a correct operation of the strap that for the maximum angular variation α of the elements relatively to the mean position, the distance between the two centres of curvature C_2C_3 be greater than that between the edges of both elements which are moved apart owing to that symmetrical position and that the edges moved nearer owing to it do not touch or are just in contact.

The keeping of these two conditions enables us to determine the maximum value of the radius of curvature of the rim elements, starting from the maximum angular variation, the minimum radius of the pulley and the distance between pins 7 of elements 9 and primitive circle 22.

Thus, for instance, for an angular variation not exceeding 4°, a minimum primitive diameter of 150 mm., and a distance between the pins and the primitive circle equal to 20 mm., the radius of curvature of an element may be equal to 60 mm.

The peripheral length of the element is then 55.7 mm., which corresponds to a subtended angle at the centre of 53° for that element.

The radius of curvature of an element is, in that case, three times the distance between a pin and the primitive circle of the pulley.

The proposed arrangement obviously implies, an even number of elements.

What I claim is:

1. An extensible pulley carried by a shaft comprising a sleeve adapted to rotate around said shaft; two annular flanges coaxial with said shaft and secured to the ends of said sleeve; two other flanges coaxial with said shaft and secured to it on either side of said two former flanges; pivots parallel to said shaft and secured to each of said flanges at circumferentially regularly distributed points; four sets of tie rods, the tie rods of each set being adapted to swivel at one of their ends on the pivots of each of said flanges; pins parallel to said shaft carried by the other end of one tie rod belonging to each set; and rim elements carried by said pins and located around the shaft between the sets of tie rods hinged to the former flanges.

2. An extensible pulley comprising four parallel, coaxial flanges, the two outer flanges being fast with one another and the two inner flanges being fast with one another and arranged for rotation relatively to the two outer flanges; a plurality of tie rods pivotally mounted on each of said flanges, the number of tie rods associated with each flange being the same; and a plurality of rim elements arranged for free radial displacement between the two inner flanges, each rim element being supported by four corresponding tie rods respectively associated with the four flanges.

3. An extensible pulley comprising four parallel, coaxial flanges, the two outer flanges being fast with one another and the two inner flanges being fast with one another and arranged for rotation relatively to the two outer flanges; a plurality of tie rods pivotally mounted on each of said flanges along a circle coaxial therewith and regularly distributed thereon, the number of tie rods associated with each flange being the same; and a plurality of rim elements arranged for free radial displacement between the two inner flanges, each rim element being supported by four corresponding tie rods respectively associated with the four flanges.

4. An extensible pulley comprising four parallel, coaxial flanges, the two outer flanges being fast with one another and the two inner flanges being fast with one another and arranged for rotation relatively to the two outer flanges; a plurality of tie rods pivotally mounted on each of said flanges through pivots regularly distributed along a circle coaxial therewith, the corresponding pivots carried on flanges fast with one another being coaxial, and all the tie rods associated with flanges fast with one another having the same shape and size, the number of tie rods associated with each flange being the same; and a plurality of rim elements arranged for free radial displacement between the two inner flanges, each rim element being supported by four corresponding tie rods respectively associated with the four flanges.

5. An extensible pulley according to claim 4 in which the tie-rods are angle-shaped, pivoted at one end on the corresponding flanges, and

carrying at the other end of the corresponding rim elements, the convexity of said angle-shaped tie rods being outwardly directed and the interval between successive pivots associated with a same flange being smaller than the length of the pivoted arm of the angle-shaped tie rods.

6. An extensible pulley comprising four parallel, coaxial flanges, the two outer flanges being fast with one another and the two inner flanges being fast with one another and arranged for rotation relatively to the two outer flanges; a plurality of tie rods pivotally mounted on each of said flanges, the number of tie rods associated with each flange being the same; and a plurality of rim elements arranged for free radial displacement between the two inner flanges, each rim element being supported by four corresponding tie rods respectively associated with the four flanges, said rim element being secured to the tie rods associated with one of the pairs of flanges fast with one another and hingedly

connected to the tie rods associated with the other pair of flanges fast with one another, each rim element having a substantially cylindrical operative surface the radius of curvature of which is at least equal to the distance between the support axis of the rim element and the envelope cylinder of all the rim elements.

EDMOND E. J. GAÏSSET.

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